A NOTE ON THE CLASSIFICATION OF CLIMATES*

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In the great variety of the world's climates it is essential that we have some classification, some grouping of like with like, some scheme of systematic correlation, which shall bring order out of chaos, and shall enable us to study and to describe climates in a rational and simple way. When, for example, we read the accounts of the war in the Balkans, or of the approaching opening of the Panama Canal, or of the sufferings of the wretched rubber collectors in the remote forests of the Amazon, the climatic environment in each of these cases has an immediate and live interest. We ought to be able to picture to ourselves the essential characteristics of that environment. More than that, we ought to be able to correlate the climatic environment in these three regions with other similar climates, in other parts of the world. Geographers in general, and those who have had the task of teaching climatology in particular, fully realize the great need, in their daily work and study, of a reasonably simple, rational and practical scheme of climatic classification, of a series of climatic "pigeon-holes," as it were, into which they can fit each climatic type with which they have to deal.

This subject is, in reality, a very vital one. It has, naturally enough, received much attention, from early times. On the one hand we have the various classifications of the zones, in which there are certain broad belts, divided by more or less east-and-west lines. On the other hand, when these zones have been subdivided to a considerable extent, we have our classifications of climates, our climatic provinces or regions. The dividing line between these two sets of classifications is impossible to fix. The zones of climate gradually merge into the climatic provinces. Under the zonal groupings we have the classic subdivision of the earth's surface on the basis of the distribution of sunshine, which dates back to the time of the early Greek philosophers, and which has given us our familiar five-zone division, so simple, so long used, so well known, and, in spite

*Cf. also, by the same author, "The Climatic Zones and Their Subdivisions" and "The Classification of Climates," in this *Bulletin*, Vol. 37, 1905, pp. 385-396, and Vol. 38, 1906, pp. 401-412, 465-477, respectively (Chapters I, II and III of the author's subsequent book "Climate, Considered Especially in Relation to Man," 1908, reviewed in the *Bulletin*, Vol. 40, 1908, p. 490). ED.

of its not according well with the facts of climate, still on the whole so satisfactory to the vast majority of people. The fact that these astronomical zones—i. e., the zones of sunshine—differ a good deal from the zones of heat, naturally led to the limitation of the climatic zones by isotherms rather than by parallels of latitude. Thus Supan[1] gave us his temperature zones, in which the mean annual isotherm of 68° and the isotherm of 50° for the warmest month are taken as rational boundaries, replacing an earlier and more complicated scheme[2], by the same authority, in which some less critical temperatures had been selected as limiting lines. Another classification of temperature zones was suggested by Köppen,[3] in which the length of time during which the temperature remains within certain fixed limits is taken into account, these limits having well-marked relations to the life of plants. Two critical (daily mean) temperatures, 68° and 50°, and the duration of these temperatures for periods of 1, 4 and 12 months, are the factors in this scheme, the temperatures not being reduced to sea-level. While this method of classification is rational in emphasizing the very important element of temperature, and the scheme is particularly useful in special studies of plant distribution, it is rather too detailed for general adoption. The grouping of the climatic zones according to the systems of the prevailing winds, as suggested by W. M. Davis,[4] has much to recommend it from a meteorological standpoint, for the great wind belts are associated with the great rain and cloud belts, and have their own distinctive climatic characteristics. But the classification by wind systems involves a shifting of the boundaries of the zones with the seasons which, while logical and natural, nevertheless does involve a good deal of confusion. Woeikof's compromise suggestion,[5] between the limits set by latitude lines in the Greek scheme and those set by the winds, loses some of the advantages of each of these schemes, and gains but little in return.

While a broad division of the earth's surface into zones is necessary as a first step in any systematic study of climates, as soon as a more detailed discussion is undertaken there comes an inevitable need of a more detailed climatic subdivision. Thus, we have the familiar grouping into continental and marine climates, with the

[1] A. Supan: Grundzüge der physischen Erdkunde, 5th edit., 1911, pp. 98-100 and Pl. VIII (originally published in 1896).

[2] *idem:* Die Temperaturzonen der Erde, *Petermanns Mitt.*, Vol. 25, 1879, pp. 349-358 and Pl. 18.

[3] W. Köppen: Die Wärmezonen der Erde., etc., *Meteorol. Zeitschr.*, Vol. I, 1884, pp. 215-226.

[4] W. M. Davis: Elementary Meteorology, 1894, pp. 334-335.

[5] A. Woeikof: Die Klimate der Erde, 1887, Part I, p. 327.

modifications in desert, littoral, monsoon, and mountain and plateau types. It is obvious that an almost infinite number of classifications of climates might be proposed, for we may take as the basis of subdivision either the special conditions of one climatic element, or similar combinations of two or more elements. Some of the suggested classifications are well known; others are practically unknown. In Supan's scheme[6] there are 35 climatic "provinces." Each is numbered and named, and its essential characteristics are briefly described. But there is no correlation between similar climates in different parts of the world, although, as is well known, many of the larger types recur on the several continents in fairly systematic fashion. Thus, in Supan's scheme, the characteristics of each province must be learned for and by themselves, although every careful student will himself recognize the points of resemblance in many cases, and will naturally come to associate provinces which have different numbers and different names together. Köppen[7] proposed an interesting classification of climates which depends upon certain values of the temperature and rainfall of the warmest and coldest month, or of the wettest and driest month, thus combining the two elements of precipitation and temperature. Five principal groups of plants constitute the major divisions, and these are subdivided until the whole number of "climates" reaches 24. The special conditions which characterize each of these climates are carefully determined, and each sub-climate is given a distinctive name. This elaborate scheme is too complicated for ordinary use, but it is of great value to students of plant geography. Then we have Penck's suggestion[8] for subdividing climates, not on a rigid meteorological basis, in which accurate observations are necessary, but according to certain large and readily recognizable features of surface form, of glaciation, and of the relation of evaporation and rainfall—a sort of "car window" classification of climates, both simple and useful; and de Martonne's new climatic provinces[9] and Hult's little-known and elaborate scheme[10] which includes more than 100 small provinces; and Ravenstein's "hygro-

6 A. Supan: Grundzüge der physischen Erdkunde, 5th edit., 1911, pp. 230–234 and Pl. XV (first published in 1903).

7 W. Köppen: Versuch einer Klassifikation der Klimate, vorzugweise nach ihren Beziehungen zur Pflanzenwelt, *Geogr. Zeitschr.*, Vol. 6, 1900, pp. 593–611 and 657–679, with Pls. 6 and 7.

8 A. Penck: Versuch einer Klimaklassifikation auf physiogeographischer Grundlage *Sitzungsberichte der Preussischen Akad. der Wiss.*, 1910, Vol. XII, pp. 236–246.

9 E. de Martonne: Traite de Géographie Physique, 2nd edit., 1913, Chapter VI of Section 2, with Carte des Climats (unaltered from first edition).

10 R. Hult: Jorden's Klimatområden, *Vetenskap. Meddelanden af Geogr. Föreningen i Finland*, Vol. I, 1892–93, pp. 140–201, with Pl. XVI.

thermal types,"[11] suggestive, but resting upon incomplete and unsatisfactory data. We ought also to make mention of the numerous classifications of rainfall types and seasons, such as that of Köppen, for instance.

It is obvious that, as noted above, there is really no limit to the number of such classifications, for there is no limit to the number of combinations of the various climatic elements which may be taken as the basis for the subdivisions. Some will prefer one scheme. Others will prefer another. There is, and there can be, no general agreement as to *the best.* Indeed, the whole matter is a difficult one. The fact that several of the authors who have given us carefully considered schemes have themselves changed their own maps is a pretty good indication that a fixed and satisfied state of mind is difficult to attain.

Among those who have given much careful attention to this subject of late years is Professor A. J. Herbertson, of the School of Geography, University of Oxford. In 1905 Dr. Herbertson[12] published his first map of so-called "Major Natural Regions," the basis of this classification being, not a certain definite value of a single climatic element, or of a fixed combination of two or more elements, but a certain unity of temperature, rainfall seasons, configuration and vegetation. The original scheme was somewhat revised in 1907,[13] and, if we are not mistaken, has been again slightly revised for the Oxford Wall Maps series.* The different types of natural regions recur in fairly systematic order on the different continents, being chiefly controlled by marine and continental influences, and each type, wherever found, has certain similar general relations to human life and development. This scheme, therefore, in which a particular type of natural region has the same number, wherever it is found, is especially helpful in all studies of world climatology, as well as in investigations of the economic and political history of mankind. The chief characteristics of each type having been learned, and the geographic distribution of the types being known, the grouping of the natural regions, while not exactly a classification of climates, is one of the best working schemes for a systematic study of climatology. The present writer can testify to the great value of this classification because of its rational, simple and effec-

[11] E. G. Ravenstein: The Geographic Distribution of Relative Humidity, *Report Brit. Assoc. Adv. Sci.*, 1900, pp. 817-818.

[12] A. J. Herbertson: The Major Natural Regions: An Essay in Systematic Geography, *Geogr. Journ.*, Vol. 25, 1905, pp. 300-312 (map on p. 308).

[13] The Senior Geography, Oxford, 1907, frontispiece.

* See, under "World," *Bulletin*, Vol. 45, 1913, p. 640. Ed.

tive correlation of climates and conditions of life. He has found it the best working scheme of all that have thus far been suggested.

In investigating the essential qualities of his different natural regions—the climatic characteristics which give them their distinctive effects—Dr. Herbertson has been making a special study of temperature conditions. The various steps which have been taken in this work, leading eventually to the construction of a new map of thermal regions, are briefly described in a recent paper on "The Thermal Regions of the Globe,"[14] this being the abstract of a paper presented at a meeting of the Research Department, Dec. 14, 1911. In all of his studies, Dr. Herbertson has been endeavoring to find out what are the best methods of representing the thermal conditions of the earth's surface for the use of geographers. It is no exaggeration to say that few investigators have extracted so many important facts from the ordinary isothermal charts.

In the course of his studies, Dr. Herbertson has constructed several different isothermal maps.† Beginning with the mean annual temperatures reduced to sea-level, and realizing that the ordinary isothermal map, with its many lines, is very confusing, a choice was made of three critical lines, those of 32°, 50° and 68° Fahr., and a mean annual temperature map was prepared with these isotherms drawn upon it. The selection of these particular isotherms is justified on several grounds, and we cannot help feeling that if teachers generally, in using the mean annual isothermal map in their classes, would emphasize the location of these particular isotherms (70° may be taken in place of 68° and 30° in place of 32°, if these are not on the chart in use), perhaps having them drawn in in heavier lines, their students would gain a clearer idea of the essentials of the map. Yet, as everyone knows, mean annual temperatures are unsatisfactory, indeed often misleading, for they do not give any clue to the seasonal variations Recognizing this fact, Supan, as above noted, in his map of temperature belts, used, in addition to the mean annual isotherm of 68° the isotherm of 50° for the warmest month, thus giving a very simple but rational series of temperature zones. Dr. Herbertson, going a step further, has published a map showing the thermal zones obtained by using the isotherms of 32°, 50° and 68° for the warmest and coldest months, and indicating these different zones by different styles of shading. This map (Fig. 3 of Dr. Herbertson) is made by superposing the Janu-

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[14] *Geogr. Journ.*, Vol. 40, 1912, pp. 518–532.

† Reviewed under "World" in the *Bulletin*, Vol. 45, 1913, p. 80. Ed.

ary and July maps showing the 32°, 50° and 68° sea-level isotherms, a construction which we have ourselves used effectively in laboratory work in climatological instruction. Many of the most important facts as to range of temperature are clearly brought out by this method, and the student furthermore gains a clear idea of the seasonal migration of isotherms, and of the progress of the seasons. A further step, along the same lines, has been taken by Dr. Herbertson in the construction of a "thermal zone" map based upon the seasonal isotherms of 32°, 50° and 68°. This chart is not reproduced in the paper under discussion.

The maps just referred to concern sea-level temperatures. All meteorologists recognize the importance of sea-level isothermal maps in showing the large facts of temperature distribution; the effects of continents and oceans; of ocean currents and of winds; and appreciate the difficulty and uncertainty of constructing isothermal charts showing actual temperatures, not reduced to sea-level. Yet no serious student of geography can have failed to realize that sea-level isotherms are often most unsatisfactory, insufficient and misleading. One who has gained his knowledge of the climate of some moderately elevated region from sea-level isothermal maps alone, without allowing for the altitude, will, on actually visiting that locality, often experience a curious sensation of surprise and of disappointment, when he finds that his preconceived notions as to the temperature are quite erroneous. Thus it has come about that there has been a marked tendency of late years to chart actual air temperatures. Dr. Herbertson has made a valuable contribution to our existing series of isothermal charts by drawing the actual January and July isotherms of 32°, 50° and 68°, whose positions he determined (using contoured maps and allowing for the altitudes) with great care. The land areas are distinctively colored, and, for purposes of comparison, the sea-level isotherms of these same values have been included (Figs. 4 and 5). This method of showing actual rather than sea-level temperatures brings out several points of much importance. For example, the sea-level isotherm of 32° in January crosses North America from south of Vancouver Island to south of the Great Lakes, yet some of the sections with an actual temperature below freezing extend as far south as the sea-level temperature of 50°. Again, in Asia, the 32° line of actual temperature comes much farther south in Tibet than does the sea-level isotherm of 50°. In July, on the other hand, the actual isotherms show that Tibet has a relatively low temperature, a condition quite

different from that indicated on the ordinary sea-level isothermal chart. By superposing the January and July maps Dr. Herbertson was able to construct his chart of Thermal Regions (Fig. 7) which, together with the two monthly maps, has been reproduced, in colors, in the series of Oxford Wall Maps (60x40 inches). This wall-map we have found extremely useful in class-room work. A comparison, in the laboratory, between the sea-level and the actual temperatures is always an interesting and instructive exercise. Several striking facts at once impress themselves upon the mind. The relatively cool area over the East African plateau, within the "hot belt," and the extension of the area of "warm summers, cold winters" from northern Eurasia down into Tibet, are two of the most notable features. This map of thermal regions, then, comes much nearer the facts of existing climates than do any of the sea-level isothermal maps. Teachers of geography who want to present the real facts, rather than the somewhat ideal picture, will find it extremely useful.

In his endeavor to give still more information about the actual temperature conditions, "without undue complexity," Dr. Herbertson next proceeded to construct thermal maps to show the number of months with temperatures above 68°, above 50° and below 32°. The general idea, therefore, is not wholly unlike that embodied in Köppen's chart of temperature zones above referred to. From the available standard temperature-tables new tables were prepared giving the number of months with temperature over 68°, over 50° and under 32°. The numbers were then entered on large-scale maps, and the height of each station was noted on another set of maps. These maps were on tracing paper, to permit superposition. Next the line was drawn separating regions where at least one month has a mean temperature of 50° and those where no month has such a temperature; and so on. Where mountainous countries were being dealt with, valleys and plateaus, not the highest parts of the ranges, were considered. Figure 7 of the paper under discussion shows the results, the land areas being shaded to indicate the different numbers of months (1, 3, 5, 7, 9, 11) with temperatures over 50°. Dr. Herbertson points out that the line between three and four months over 50° is important, because it indicates roughly the northern limit of profitable wheat-growing, at least in eastern North America. Another map, showing the number of months over 68°, and one showing the number of months under 32°, were also prepared, and from these three a new map of Thermal Regions (Fig. 8)

was constructed, which is perhaps the most complete representation of the actual temperature conditions of the world on a single map hitherto published. There are in all fifteen different regions (one embracing all lands over 4,000 meters in altitude), which differ from one another in the numbers of months with temperatures over or under 32°, 50° and 68°. In spite of the number of regions, the map is singularly clear and distinct. It is difficult to imagine how mean monthly temperatures could be more clearly and effectively shown on one map than is here the case. The region where no month has over 50° coincides roughly with the tundra. An important region is the one with at least four months over 50°, and with four or five months below 32°. In passing from the continental interiors westward the number of months over 50° does not change, but there is a decrease in the number of months with frost. While central Europe has less than four months of frost, western Europe has no month with a mean temperature under 32°. There is nothing in eastern Asia corresponding with the British Isles, France and the Low Countries of Europe, but we find that same milder northwestern European region in western North America, in southern South America, in Tasmania and in New Zealand. In North America the zone with from one to three frosty months but with at least three months over 50° marks roughly the northern limit of corn cultivation. In Africa the altitude gives areas within the great hot belt which, Dr. Herbertson says, "are distinctly more temperate than any other part of this belt except in the Andes." There are many other points of interest which might be referred to.

In considering Dr. Herbertson's new map of thermal regions, it seems to us that both in his selection of the critical monthly temperatures, and in his working out of the thermal regions, our author has shown excellent judgment. It must be obvious to everyone that the duration of these critical temperatures is of great importance in the distribution of vegetation and of crops. We feel sure that physicians and many others who have a peculiar interest in temperature will find the map most useful, and that teachers of geography will be able to bring out many important facts by their use of it in their classes. For a quick determination of the essential temperature conditions of any region, the new map is admirably adapted. There are, of course, several points which may be urged on the other side. There are manifest difficulties, which our author recognizes, in constructing the map in regions where there are great differences of altitude, and it would, per-

haps, seem wiser not to attempt to introduce quite so much detail in a map which cannot, for ordinary use, be on a very large scale. Botanists will probably say that they have more interest in extremes of temperature, and in the seasonal rise and fall, or in the diurnal variability, than in the monthly means. Other persons will say that the temperatures without the rainfall mean little. Others, again, will ask for data regarding cloudiness, or evaporation. But, as we have said, these maps are maps of thermal regions, and they lay no claim to being anything else. And, moreover, we understand that Dr. Herbertson's object in constructing them was primarily in order that there might be discussion of the different methods by which the temperature conditions may best be represented for the use of geographers. For our own part, we feel under great obligations to Dr. Herbertson for his painstaking work on these numerous temperature charts, and especially for his emphasis upon the importance of the actual as contrasted with the sea-level temperatures. Those who have spent most of their lives in becoming familiar with sea-level isotherms will have a wholly new and a far more rational view of the world's temperatures as the result of their familiarity with Dr. Herbertson's work. The more widely his charts are known and used, the clearer and the more accurate will be our meteorological knowledge. It is a fortunate circumstance that the January and July actual temperatures, and the thermal regions map based upon them, are already available in the excellent series of Oxford Wall Maps. We hope that the new thermal region map, based upon the numbers of months above and below certain temperatures, will soon be added to the Oxford Series.

We sincerely hope that Dr. Herbertson will continue his interesting studies, and will, before long, be able to give us, in brief numerical form, the essential climatic characteristics of his Major Natural Regions. With that addition we believe that his scheme of subdivision of the earth's surface into "natural regions" will meet the needs of most geographers who are in search of a rational, simple, "working" classification of climates.